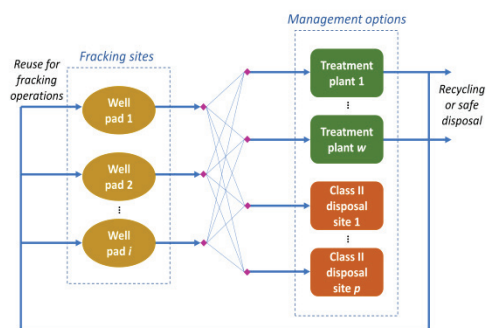


## Robust Stochastic-Fuzzy Modelling Approach for Shale Gas Wastewater Management under Uncertainty

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Shale gas wastewater management system



Shale gas has attracted growing investments as a new resource to increase primary energy supply, with impact on global energy markets. Over the last decade, advances in horizontal drilling and hydraulic fracturing «fracking» technologies have boosted the natural gas production from tight shale formations. Notwithstanding, shale gas exploration is still a controversial topic since its environmental and social implications are far from being totally elucidated. Concerning wastewater-related impacts alone, shale gas extraction generally produces large volumes of polluting hypersaline wastewater [1]. Hence, wastewater management is especially challenging to enhance overall process efficiency and sustainability in shale gas industry [2].

In this work, a new stochastic-fuzzy-based modelling approach is introduced for the robust optimization of shale gas wastewater management under multiple sources of uncertainty. Different management alternatives are considered to deal with the wastewater produced from fracking sites (well pads), including treatment plants—composed by pre-treatment and zero-liquid discharge (ZLD) desalination units—to allow water recycling or internal reuse in shale gas operations, or final disposal in Class II saline water injection wells (i.e., conventional deep-well injection). Thus, the model is aimed at obtaining an optimal shale gas wastewater network by improving the process cost-effectiveness, while accounting for several planning periods with different wastewater generation scenarios, and uncertain capacities of treatment plants and disposal wells. In this new approach, wastewater flowrate and salinity are

both considered as uncertain correlated parameters described by a set of generation scenarios with a given probability of occurrence. The wastewater generation scenarios are obtained via Monte Carlo sampling technique from a multivariate normal (Gaussian) distribution with symmetric correlation matrix. Uncertain treatment and disposal capacity constraints are mathematically modelled through fuzzy membership functions at different feasibility degrees, and probability functions by stochastic chance-constrained fuzzy programming [3].

The resulting multiscenario stochastic-fuzzy MINLP-based model is implemented in GAMS (version 24.8.5), by minimizing the expected total annualized cost. The objective function accounts for the contributions associated with the capital investment in the expansion of treatment plants (scenario independent decision variable) in the strategic planning periods, and operating expenses (scenario-dependent decision variables) related to transportation, pre-treatment and desalination and disposal in Class II wells, and revenues from water internal reuse in new fracking operations.

Results from risk analysis reveals optimal trade-offs between economic performance and system reliability. This methodology is a useful tool to support decision-makers towards the application of more robust and reliable systems for shale gas wastewater management.

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